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# New Taxa and New Records of Patelliform Gastropods Associated with Chemoautosynthesis-Based Communities in Japanese Waters

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*Abstract.* New taxa and new distribution records are described for limpets collected by recent dives of *Shinkai 2000* from chemoautosynthetic environments around the Japanese archipelago. They include five new, three described, and two unidentified species in five families of Patellogastropoda, Cocculiniformia, Vetiagastropoda, and Neritopsina. *Bathyacmaea* ***tertia***, *B.* ***subnipponica***, *Serradonta* ***kanesunosensis*** (Acmaeidae), *Pyropelta* ***yamato*** (Pyropeltidae), and *Shinkailepas* ***myojinensis*** (Shinkailepadidae) are described as new species. *Pyropelta yamato* represents the first record of the Pyropeltidae from the Northwest Pacific. *Serradonta* ***kanesunosensis*** is also noteworthy as the second species of the genus which is known only from Japanese vent/seep sites. A review of faunal data revealed that all Japanese limpets so far known from chemoautosynthetic environments are endemic to either vent or seep habitat and confined to a narrow geographic distribution.

## INTRODUCTION

Numerous new organisms have been discovered in chemosynthesis-based biological communities occurring along active subduction zones, spreading zones (mid-ocean ridges), escarpments, submarine volcanoes, oil seepages, whale bones, etc. in world oceans since the discovery of Galapagos rift fauna in 1977. The fauna at vent/seep sites is obviously separated from non-chemosynthetic deep-sea fauna by a high degree of endemism at not only the species but also higher-taxon levels, as recently reviewed by Warén & Bouchet (2001) in gastropods. Limpets, or patelliform gastropods, are one of the important faunal elements in such specialized habitats and communities. They were variously called "hot-vent limpets" at an early stage of systematic studies (e.g., Hickman, 1983; Haszprunar, 1988), and provided the major impetus for phylogenetic considerations on Gastropoda as a whole. Even at present, the systematic position of some "vent limpets," such as Neomphaloidea, has not yet been at all resolved (Ponder & Lindberg, 1997; Sasaki, 1998; McArthur & Koop, 1999).

Many chemosynthesis-based vent or seep sites have been discovered around Japan since the Japan Marine Science and Technology Center (JAMSTEC) initiated deep-sea surveys in 1983 by using the manned submersible, *Shinkai 2000* (see Kojima, 2002 for review). As a result, huge aggregations of *Calyptogena* Dall, 1891, and other mollusks have been reported at many sites along trenches, troughs, and submarine volcanoes; and intensive investigations have been carried out on molluscan faunas of some geographic regions (e.g., Okutani et al., 1992, 1993; Okutani & Fujiwara, 2000; Okutani & Fujikura, 2002; Fujikura et al., 2002) and some taxonomic groups (e.g., Okutani et al., 1989, 2000; Okutani & Fujikura, 1990, 1992; Hashimoto & Okutani, 1994; Okutani & Hashimoto, 1997). In typical taxon-based studies, a series of prior descriptions of Japanese *Calyptogena* were recently reviewed thoroughly in terms of systematics (Okutani et al., 2000) and distribution (Fujikura et al., 2000). The gastropods from Japanese vent/seep localities, however, have been described only sporadically and are still relatively poorly known. This study focuses on systematic descriptions of limpets, which constitute a conspicuous part of gastropod fauna at most localities in Japan. Morphological observations were made on shell, radular, and opercular (if present) characters, and their morphology was compared with that of species previously recorded from Japanese and non-Japanese sites.

## MATERIALS AND METHODS

The limpet specimens treated in this paper were all collected by *Shinkai 2000* except a single dredged sample (Table 1). They were collected by 14 dives at six localities (Figure 1). Specimens were fixed in buffered formalin, and later transferred to 70% ethanol. A scanning electron microscope (Hitachi S-2400 in the Department of Earth and Planetary Sciences, University of Tokyo) was used to observe the shells of small species and the

Table 1

Source of the present material.

| Locality | Dive* | Date | N. latitude | E. longitude | Depth (m) |
|---|---|---|---|---|---|
| North Knoll of Iheya Ridge | 672 | May 14, 1993 | 27° 33.00 | 126° 58.00 | 1390 |
| North Knoll of Iheya Ridge | 863 | May 7, 1996 | 27° 47.18 | 126° 54.15 | 1049 |
| North Knoll of Iheya Ridge | 975 | September 21, 1997 | 27° 47.22 | 126° 53.92 | 976 |
| North Knoll of Iheya Ridge | 978 | September 25, 1997 | 27° 47.17 | 126° 53.91 | 990 |
| North Knoll of Iheya Ridge | 1094 | May 8, 1999 | 27° 47.22 | 126° 53.91 | 996 |
| North Knoll of Iheya Ridge | 1094 | May 8, 1999 | 27° 47.02 | 126° 54.00 | 1000 |
| Izena Hole | Dredge** | June 25, 1989 | 27° 16.00 | 127° 05.00 | 1430 |
| Izena Hole | 360 | September 3, 1998 | 27° 16.00 | 127° 05.00 | 1430 |
| Kanesunose Bank | 770 | November 24, 1994 | 34° 17.5 | 138° 15.0 | 273–290 |
| Kanesunose Bank | 772 | November 26, 1994 | 34° 17.5 | 138° 15.0 | 284–304 |
| Kanesunose Bank | 816 | October 2, 1995 | 34° 17.06 | 138° 14.86 | 322 |
| Myojin Knoll | 1112 | June 29, 1999 | 32° 06.2 | 139° 52.0 | 1288–1340 |
| Myojin Knoll | 1115 | July 3, 1999 | 32° 06.2 | 139° 52.0 | 1260–1290 |
| Ryuyo Canyon | 898 | September 16, 1996 | 34° 11.50 | 137° 45.50 | 1110 |
| Sumisu Caldera | 1017 | May 26, 1998 | 31° 27.97 | 140° 04.44 | 676 |

* Dive number of *Shinkai 2000.*
** Cruise DK89-1-OKN Leg.2.

radulae of all species. Soft tissue enclosing radulae was chemically dissolved in a commercial bleach without heating. The time of treatment was not constant but greatly variable, depending on the size of the specimens. Observations of radular teeth were made at non-abraded portions of anterior rows.

Holotypes and a few selected paratypes of new species and illustrated specimens of all species were registered and deposited in the Department of Historical Geology and Paleontology, The University Museum, The University of Tokyo (UMUT). The remaining large number of paratypes and other non-new taxa are preserved in the collection of Japan Marine Science & Technology Center (JAMSTEC). In the descriptions, the following abbreviations are used: SH = shell height, SL = shell length, SW = shell width.

## SYSTEMATIC DESCRIPTIONS

### Class GASTROPODA

### Subclass EOGASTROPODA

### Order PATELLOGASTROPODA

### Family ACMAEIDAE Forbes, 1850

### Genus *Bathyacmaea* Okutani, Tsuchida & Fujikura, 1992

**Diagnosis:** Shell patelliform, pure white; apex central to slightly anterior; surface often eroded, roughened with exposed inner foliated layer. Radula docoglossate with formula 0-1-0-1-0; lateral teeth elongate with straight shaft, aligned obliquely; their tips divided into three cusps; basal plate thick, marked by single pair of scars of lateral teeth.

### *Bathyacmaea secunda* Okutani, Fujikura & Sasaki, 1993

(Figures 2, 3A)

*Bathyacmaea secunda* Okutani, Fujikura & Sasaki, 1993: 130, figs. 13–19; Okutani & Fujiwara, 2000: 124, figs. 2–3; Sasaki, 2000: 27, pl. 13, fig. 5.

**New records:** 60 specimens in JAMSTEC (008465 to 008524) from North Knoll of Iheya Ridge, 1049 m deep, *Shinkai 2000* Dive 863; 2 specimens in JAMSTEC (006610 to 006611) from North Knoll of Iheya Ridge, 990 m deep, *Shinkai 2000* Dive 978; 15 specimens in JAMSTEC (010739 to 010753) from the same locality, 1390 m deep, *Shinkai 2000* Dive 672; a single specimen in JAMSTEC (010951) from Izena Hole, 1430 m deep, Dredge: DK89-1-OKN Leg. 2.

**Distribution:** Minami Ensei Knoll, near Amami Islands, Izena Hole and North Knoll of Iheya Ridge, all in Okinawa Trough, 700 to 1430 m deep.

**Remarks:** The shell of this species is characterized by having (1) a wide circular shell aperture whose SW/SL ratio is approximately 0.9, (2) exterior ornamentation with weakly granular radiating threads, (3) a broad extension of the marginal area in ventral view (Figure 2B), and (4) a prominently extensive form of outermost cusp of the lateral tooth (Okutani et al., 1993: figs. 18, 19). The habitat is restricted to bathyal chemoautosynthetic environments in the Okinawa Trough region.

### *Bathyacmaea* ***tertia*** Sasaki, Okutani & Fujikura, sp. nov.

(Figures 3B, 4, 5)

**Type material:** Holotype (UMUT RM27955); paratype #1 (UMUT RM27956); paratype #2 (UMUT RM27957),

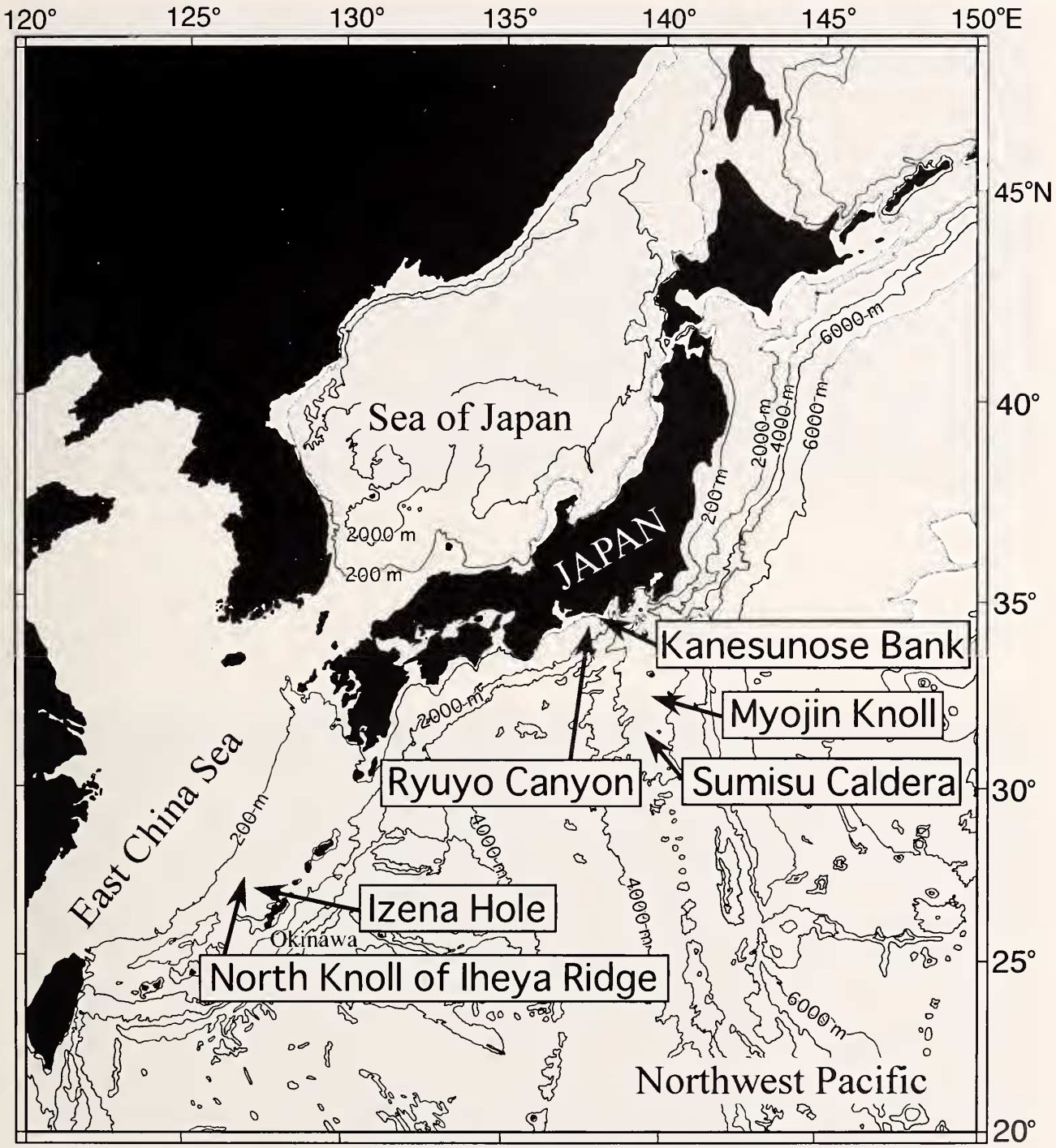



Figure 1. Localities of material examined.

all from North Knoll of Iheya Ridge, 996 m deep, *Shinkai 2000* Dive 1094; a single specimen in JAMSTEC (016365) from the same locality, 1000 m deep, *Shinkai 2000* Dive 1094.

**Diagnosis:** Surface smooth, lacking granular radial riblets and rough growth rings. Aperture oval. Anterior and posterior slopes straight to slightly concave in lateral view. Radular teeth with obtuse innermost cusp, thin and trans-

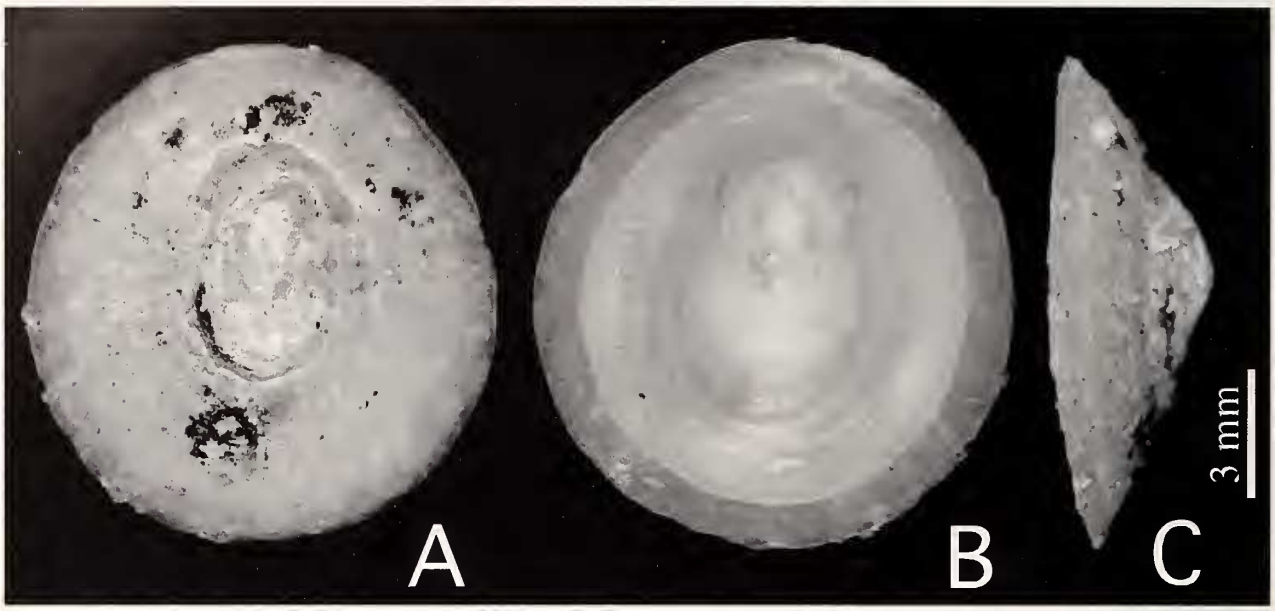



Figure 2. *Bathyacmaea secunda* Okutani, Fujikura & Sasaki, 1993. UMUT RM27953. North Knoll of Iheya Ridge, 990 m deep, *Shinkai 2000* Dive 978.

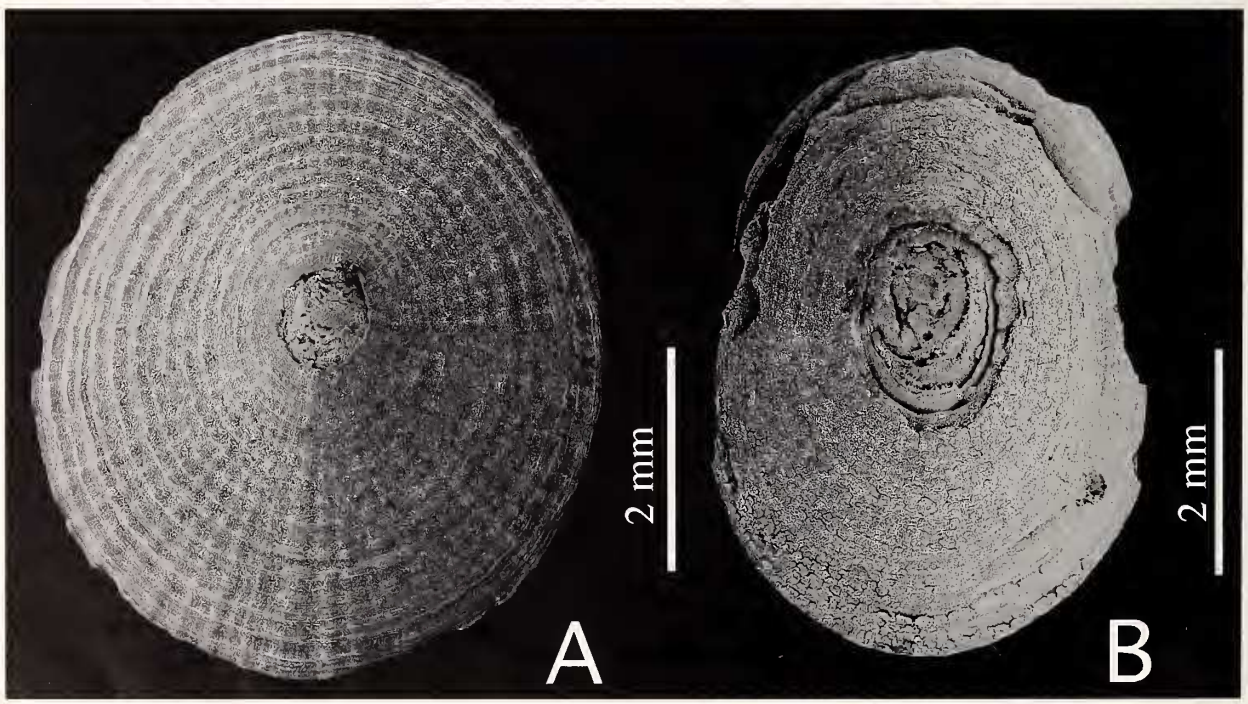



Figure 3. Juveniles of two *Bathyacmaea* species. **A.** *Bathyacmaea secunda* Okutani, Fujikura & Sasaki, 1993. UMUT RM27954. North Knoll of Iheya Ridge 990 m deep, *Shinkai 2000* Dive 978 **B.** *Bathyacmaea* ***tertia*** Sasaki, Okutani & Fujikura, sp. nov. UMUT RM27958. North Knoll of Iheya Ridge 1000 m deep, *Shinaki 2000* Dive 1094.

versely straight middle cusp, round-shouldered and enrolled outermost cusp, and stout shaft without longitudinal furrow.

**Description:** Shell patelliform, oval, longer than wide; SW about 75–81% of SL. Apex moderately high; heavily eroded; SH 36–42% of SL. Exterior surface opaque white, ornamented with dense incremental lines and microscopic radial threads, exhibiting delicate clothlike sculpture, lacking ribs and granular sculpture, partially encrusted with black substance. Interior surface clearly divisible into four commarginal circular zones from edge to apical center, *viz.* marginal, intermediate, muscle scar, and inner zones. Marginal zone opaque, thinly extended, fragile. Intermediate and central areas thickened in white. Muscle scar composed of two elements, thinner scar of pallial muscle anteriorly and thicker horseshoe-shaped scar of pedal retractor muscle posteriorly. Anterior and posterior slopes in lateral view almost straight to slightly concave. Apertural margin straight in lateral view.

Radula docoglossate with formula 0-1-0-1-0 [laterals counted as single pair rather than three because of entirely undivided shafts and corresponding scars on basal plates]. Lateral teeth elongated with tripartite cusps and straight, stout shaft. Innermost cusp sickle-shaped, slenderest among three, situated in more anterior position than other two, demarcated from shaft by longitudinal groove (Figure 5A). Middle cusp oblique to innermost cusp, broadly triangular, with shallowly concave top and sharp straight transverse edge. Outermost cusp oblique to middle cusp, reflected dorsally with slightly concave cutting edge (Figure 5B), fused with middle cusp on shaft.

**Measurements (SL × SW × SH in mm):** Holotype 12.5 × 7.0 × 5.7, paratype #1 11.1 × 9.0 × 3.3, paratype #2 12.2 × 9.5 × 4.4.

**Distribution:** North Knoll of Iheya Ridge, Okinawa Trough, 996–1000 m deep.

**Etymology:** The species name is "the third" in Latin, as this is the third species of the genus from Japanese waters. This does not mean the third discovery of the member of the genus, as another species of this genus has been already described from Edison Seamount (Beck, 1996).

**Remarks:** The possession of radular teeth with long shafts and tripartite cusps indicates that this taxon belongs to the genus *Bathyacmaea* established by Okutani et al. (1992). At the type locality, *B.* ***tertia*** is sympatric with *B. secunda,* but the former has a smoother surface and a more elongated aperture than the latter (Figure 3). In radular characters the difference from *B. secunda* is particularly apparent in the less widely extended outermost cup and long stout shaft lacking a longitudinal furrow (Okutani et al., 1993: fig. 19). *B.* ***tertia*** is also different from another known species *B. nipponica* in the absence of a coarsely reticulated sculpture, although the radular morphology is rather similar (Okutani et al., 1992: fig. 10).

*Bathyacmaea* ***subnipponica*** Sasaki, Okutani & Fujikura, sp. nov.

(Figure 6)

**Type material:** Holotype (UMUT RM 27959) from Ryuyo Canyon, 1100 m deep, *Shinkai 2000* Dive 898.

**Diagnosis:** Surface densely cancellated, not granular nor smooth. Aperture oval. Anterior and posterior slopes weakly convex in lateral view. Middle cusp of radula not thickened on inner side; outer cusp laterally extended with pointed tip.

**Description:** Shell (Figures 6A, B) patelliform, elongate oval; SW 74% of SL. Apex moderately high, heavily eroded, situated at anterior 43% of SL; SH 41% of SL (Figure 6C). Surface opaque white, sculptured by irregularly and densely spaced radial riblets, presenting beaded appearance, being cut by concentric incremental lines. Internal surface shining. Translucent marginal area very narrow; remaining inner areas thickened in pure white. Muscle scar consisting of thin horseshoe-shaped part and more attenuated anterior part. Anterior and posterior slopes obviously concave in lateral view. Apertural margin straight in lateral view.

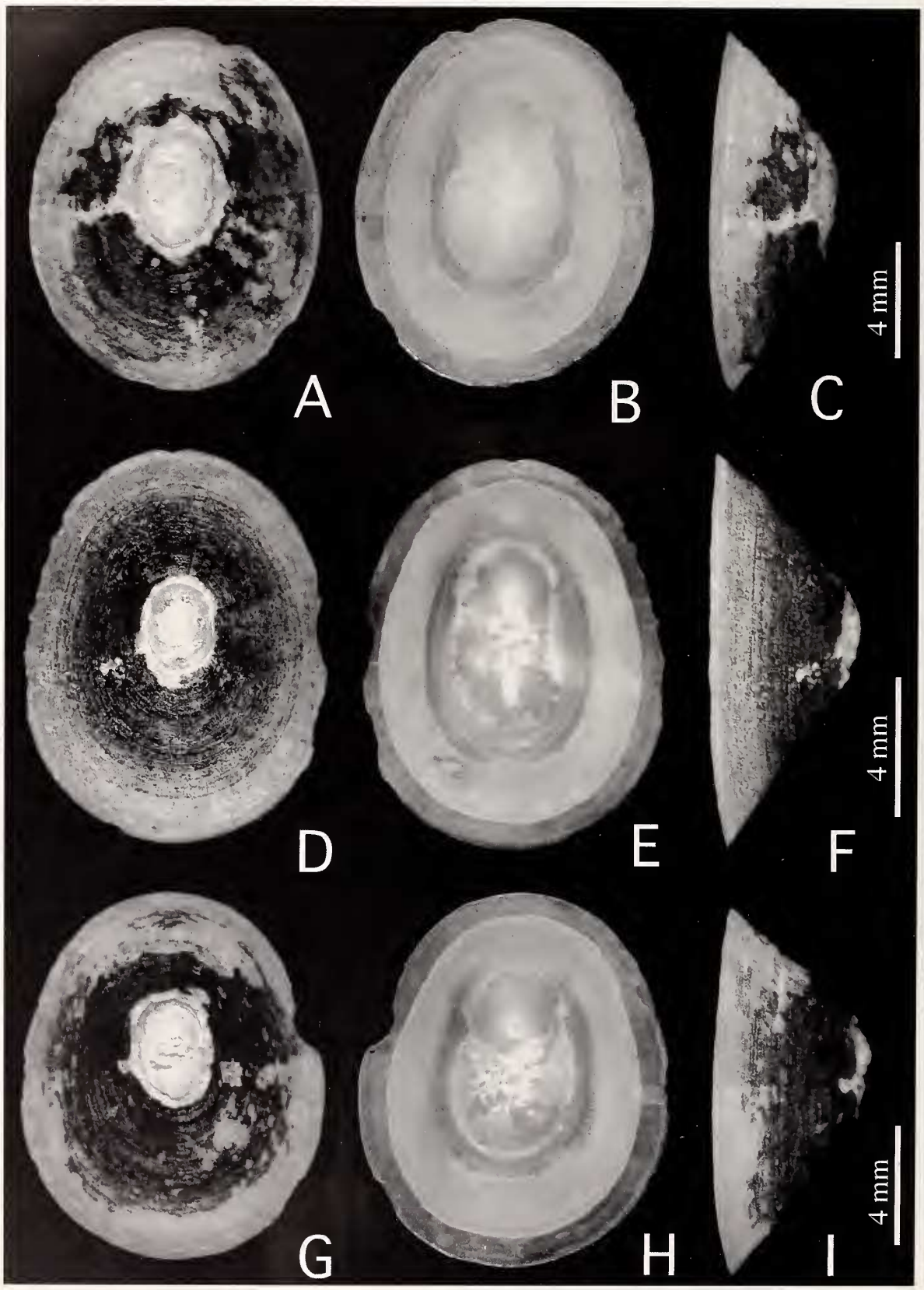
Radula docoglossate with formula 0-1-0-1-0. Lateral teeth composed of three cusps attached to anterior end of long shaft. Innermost cusp elongated with smoothly pointed tip, apparently separated from remaining two cusps but fused with ventral side of middle cusp. Middle cusp posterior to former cusp, spoon-shaped with transversely broadened straight edge, twice as wide as innermost cusp. Outermost cusp posterolateral to middle cusp, alate with outwardly pointed lobe. Shaft situated obliquely; attachment to basal plate greatly expanded. Basal plate wider than long; both anterior outer corners markedly protruded; anterior margin concave; posterior margin convex; lateral margin almost straight; prominent straight keel arising on midline. Attachment scar of lateral teeth shaft trapezoidal (Figure 6G).

**Measurements (SL × SW × SH in mm):** Holotype 9.2 × 6.8 × 3.8.

**Distribution:** Ryuyo Canyon in Nankai Trough, 1100 m deep.

**Etymology:** The species name is given to suggest a close resemblance of *B. nipponica* Okutani, Tsuchida & Fujikura, 1992, the type species of the genus.

**Remarks:** This new species resembles *B. nipponica* in having an oval aperture and densely cancellated, nongranular surface. In radular characters, however, *B.* ***subnipponica*** is clearly distinguished from *B. nipponica* (Figure 6; Okutani et al., 1992: fig. 11): the middle cusp is thicker on the inner side in *B. nipponica* but on the outer side in *B.* ***subnipponica***; the outermost cusp is elon-


A
B
C
4 mm
D
E
F
4 mm
G
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I
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gate with rounded margin in *B. nipponica* but broadened with acutely pointed tip in *B. **subnipponica***.

*Bathyacmaea* sp.

(Figure 7)

**Material examined:** A single specimen (UMUT RM27960) from Sumisu Caldera, 676 m deep *Shinkai 2000* Dive 1017.

**Description:** Shell tiny, chipped in anterior apertural area. Aperture oval; SW about 80% of SW. Apex slightly anterior to center, heavily eroded. Surface ornamented with rather regularly spaced radial riblets crossed by also regularly spaced concentric annulation, exhibiting a cancellate sculpture. Anterior and posterior slopes straight; apertural margin planar in lateral view. Radula docoglossate with formula 0-1-0-1-0. Lateral teeth with tripartite cusps. Inner cusp situated incurved, claw-shaped, at higher position. Middle cusp far broader than inner one with incurved convex top. Outer cusp triangular, acutely pointed laterally, ridgelike structure arising from basal plates sagittally.

**Measurements (SL × SW × SH in mm):** *ca.* 3 (broken) × 2.4 × 1.2.

**Distribution:** Sumisu Caldera, 676 m.

**Remarks:** A single specimen with chipped margin probably represents another new species of the genus *Bathyacmaea*. It is well characterized by having a cancellated sculpture and acutely triangular outermost cusp on the lateral teeth. However, we hesitate to establish a new taxon based on a tiny, incomplete single specimen which may not be a fully grown representative of the species.

Genus *Serradonta* Okutani, Tsuchida & Fujikura, 1992

**Diagnosis:** Shell longitudinally elongate, pure white; exterior surface devoid of prominent sculpture; apex central and elevated in highest position; aperture not flat, convex in lateral view, concave in sagittal view; anterior and posterior slopes both convex in lateral view. Radula formula 0-1-0-1-0; lateral teeth fan-shaped, very finely crenulated on cutting edge.

*Serradonta **kanesunosensis*** Sasaki, Okutani & Fujikura, sp. nov

(Figure 8)

**Type material:** Holotype (UMUT RM27961), paratype #1 (UMUT RM27962), paratype #2 (UMUT RM 27963), all from Kanesunose Bank, Nankai Trough, 322 m deep, *Shinkai 2000* Dive 816. Two paratypes in JAMSTEC from Kanesunose Bank, Nankai Trough, 284–304 m deep, *Shinkai 2000* Dive 772.

**Diagnosis:** Shell laterally compressed. Juvenile shell sculptured with concentric and radial riblets producing tubercles at their intersections but mostly smooth in adult. Inner cusp of radula strongly incurved; middle cusp indented with nine denticles; middle and outermost cusps partially overlapped.

**Description:** Shell patelliform; aperture elliptical with lateral margins somewhat parallel to each other; SW about 62% (Figure 8A) to 70% (Figure 8B) of SL. Apex situated in center (50% of SL). Surface white, ornamented with low radial riblets at early juvenile stage but diminishing distally. Concentric growth lines rather distinct, sometimes irregular. Internal surface white with horseshoe-shaped shell muscle scar. Anterior and posterior slopes convex. Apertural margin not flat; anterior and posterior margins concave; lateral margins convex in lateral view.

Radula docoglossate with formula 0-1-0-1-0. Lateral teeth lunate, fan-shaped, consisting of three elements. Innermost cusp incurved like hook with pointed tip, situated at anterior top. Middle cusp armoured with nine comblike, sharp denticles, with long shaftlike fold and cleft which are fused with bases of neighboring cusps. Outermost cusp considerably larger than former two, sharply serrated with 26 denticles.

**Measurements (SL × SW × SH in mm):** Holotype 4.9 × 2.5 × 2.1, paratype #1 4.5 × 3.0 × 2.1, paratype #2 3.7 × 2.3 × 2.0.

**Distribution:** Kanesunose Bank, 284–332 m deep.

**Etymology:** The species name is based on the name of type locality, Kanesunose Bank.

**Remarks:** This species is very similar to *Serradonta vestimentifericola* Okutani, Tsuchida & Fujikura, 1992, which was the only previously known member of the genus. They share characteristic features of laterally compressed shell with centrally positioned apex, longitudinally concave apertural margin, and a single pair of fan-shaped, tripartite lateral teeth in each radular row. The differences are, however, obvious in shell and radular characters: (1) the aperture is more prolonged longitudinally in *S. vestimentifericola*; (2) striation on the exterior shell surface disappears at juvenile stage in *S. **kanesunosensis*** but persists throughout the entire ontogeny in *S. vestimentifericola*; (3) the inner cusp is strongly incurved

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Figure 4. *Bathyacmaea **tertia*** Sasaki, Okutani & Fujikura, sp. nov. North Knoll of Iheya Ridge, 969 m deep, *Shinkai 2000* Dive 1094. **A–C.** Holotype (UMUT RM27955). **D–F.** Paratype #1 (UMUT RM27956). **G–I.** Paratype #2 (UMUT RM27957).

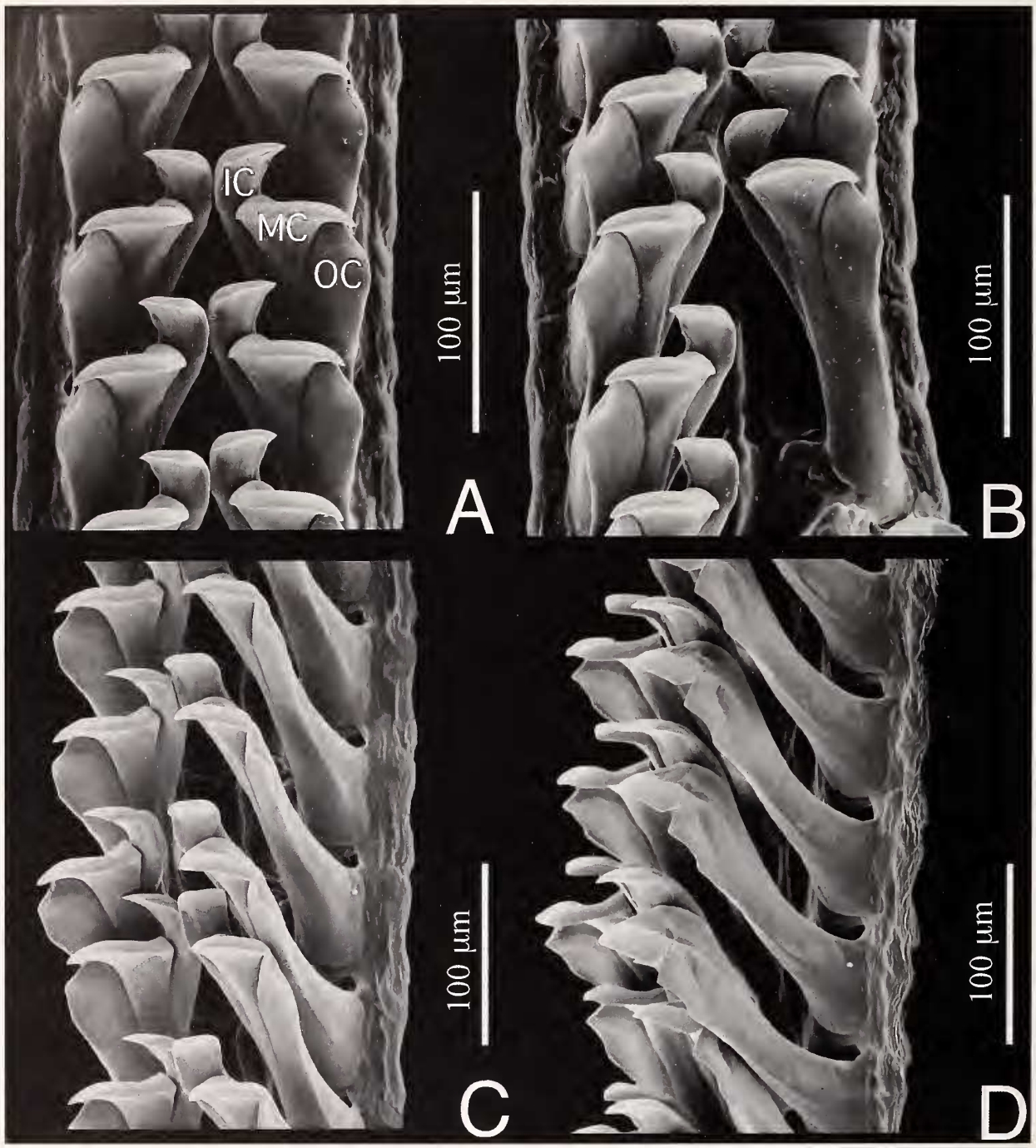



Figure 5. *Bathyacmaea* ***tertia*** Sasaki, Okutani & Fujikura, sp. nov. Radula of holotype (UMUT RM27955). North Knoll of Iheya Ridge, 969 m deep, *Shinkai 2000* Dive 1094. **A, B.** Dorsal view. Single right tooth is removed to show the shaft of tooth in figure B. IC = innermost cusp, MC = middle cusp, OC = outermost cusp. **C, D.** Inclined view showing details of cusp and base of lateral teeth on the right side.

and hooklike in *S. **kanesunosensis*** but only weakly curved and spurlike in *S. vestimentifericola*; (4) middle cups bear nine cusps in *S. **kanesunosensis*** but seven cusps in *S. vestimentifericola*; (5) middle and outermost cusps are partially overlapping in *S. **kanesunosensis*** but juxtaposed in *S. vestimentifericola*. The habitat of *S. vestimentifericola* is on a vestimentiferan tube at a seep site at bathyal depths (1110–1200 m), but the present specimens were collected from unspecified substratum in shelf zone (284–332 m). A parallel-sided concave aperture suggests *S. **kanesunosensis*** also inhabits tubular structures as in *S. vestimentifericola*.

## Subclass ORTHOGASTROPODA

## Order COCCULINIFORMIA

### Family PYROPELTIDAE McLean & Haszprunar, 1987

### Genus *Pyropelta* McLean & Haszprunar, 1987

**Diagnosis:** Shell oval to circular; apex central at highest position; surface mostly or complately eroded, sculptured by smooth concentric lines in intact area and by non-parallel, rough-edged irregular rings in eroded condition. Muscle scar undivided, horseshoe-shaped, with prominent inward processes. Radula rhipidoglossate with formula n-5-1-5-n. Central tooth broad, platelike. First to third lateral teeth in similar form and size; cusp weakly serrated, elongate longitudinally. Fourth teeth larger than remaining pairs. Bases of all lateral teeth interlocking. For anatomical characters, see McLean & Haszprunar (1987).

#### *Pyropelta **yamato*** Sasaki, Okutani & Fujikura, sp. nov.

(Figure 9)

**Type material:** Holotype (UMUT RM27964) from Sumisu Caldera, 676 m deep, *Shinkai 2000* Dive 1017.

**Diagnosis:** Aperture circular; apex depressed, nearly in center; exterior surface roughened by terraced sculpture of non-parallel increments with rough edges. Central tooth of radula hexagonal; fifth lateral teeth weakly developed.

**Description:** Shell low, tiny, patelliform; SW 91% of SL. Apex situated slightly posterior to center. Exterior surface dull white, coarsely sculptured by irregularly spaced increments which are not parallel to each other and exhibit rough edges. Aperture circular but irregular in outline in dorsal view, completely flat in lateral view. Interior surface smooth, white in color. Muscle scar horseshoe-shaped, with anterior ends greatly enlarged.

Radula rhipidoglossate with formula n-5-1-5-n. Central tooth hexagonal with roundly reflected lateral margin with tapering but truncated base; top obsolete with nearly straight margin. First to third lateral teeth similar in size and in shape, with blunt tip and delicate serrations along their sides. Fourth lateral teeth obliquely slanting, enlarged in width. Fifth lateral teeth with short cutting edge. Shaft of lateral teeth folded into L-shape; their concave inner edges interlocking with overlying next outer teeth. Fourth and fifth laterals with broadly lobate shaft unlike those of first to third laterals. Marginal teeth at least more than 30 in number of pairs, similar in size and in shape, with hooked tip and deep serration of minute spines; deep groove present below cusp; shaft weakly arcuate.

**Measurements (SL × SW × SH in mm):** Holotype 2.8 × 2.6 × 1.1.

**Distribution:** Sumisu Caldera, Izu-Ogasawara Ridge, 676 m deep.

**Etymology:** The species name "yamato" is an old name of Japan which is still used in an elegant sense.

**Remarks:** The occurrence of this species is noteworthy as the first record of the Pyropeltidae from the northwest Pacific. It is the fifth addition to four already described species, namely *P. musaica* McLean & Haszprunar, 1987, *P. corymba* McLean & Haszprunar, 1987, *P. wakefieldi* McLean, 1992, all from the northeast Pacific, and *P. bohlei* Beck, 1996, from the southwest Pacific. Among known species of *Pyropelta,* this new species is especially similar to *P. musaica* in shell morphology, particularly in its circular aperture, depressed profile, and coarsely foliated surface. However, the central tooth of the eastern Pacific species is broader in anterior margin, and the fifth lateral teeth are more prominent than in the present new species. *Pyropelta musaica* is also different in having a higher shell profile, and *P. wakefieldi* has a shorter central tooth and a more anteriorly located fifth lateral teeth than *P. **yamato***. A southwestern Pacific species, *P. bohlei,* differs in having a more elongate aperture, a broader central tooth, and a more acutely serrated fifth lateral tooth.

## Order VETIGASTROPODA

### Family FISSURELLIDAE Fleming, 1822

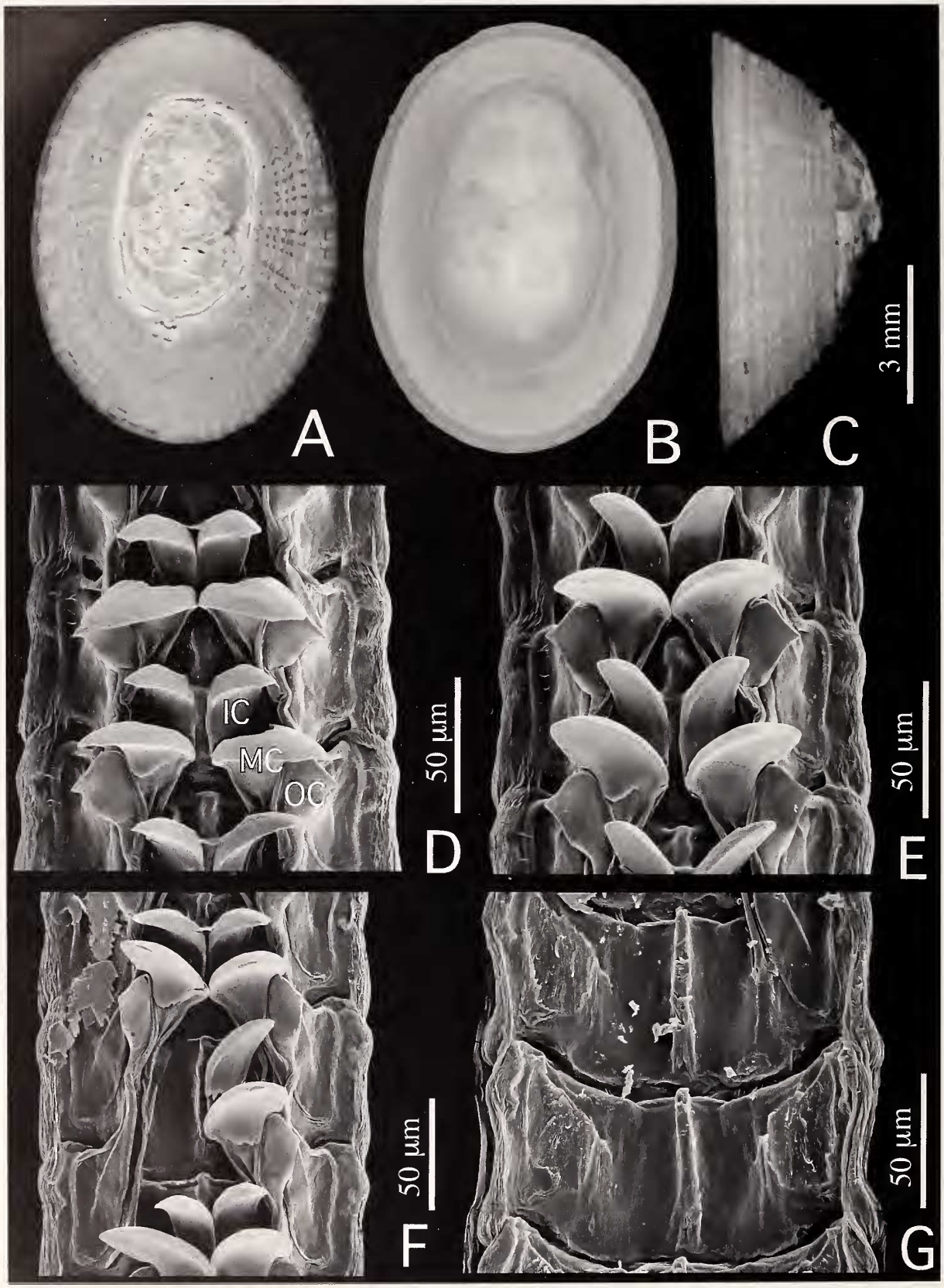
### Genus *Puncturella* Lowe, 1827

**Diagnosis:** Shell with foramen and selenizone on anterior slope; inside of foramen partially sealed with septum. Apex positioned posteriorly, protruding over posterior slope. Anterior slope convex; posterior slope concave in lateral view. Radular rhipidoglossate with formula n-5-1-5-n; central to fourth lateral teeth slender; fifth lateral teeth pronounced, pluricuspid with inner and outer denticles.

#### *Puncturella parvinobilis* Okutani, Fujikura & Sasaki, 1993

(Figure 10)

*Puncturella parnobilis* Okutani, Fujikura & Sasaki, 1993: 128, figs. 8–12; Okutani & Fujiwara, 2000: 123, fig. 4; Sasaki, 2000: 51, pl. 25, fig. 34.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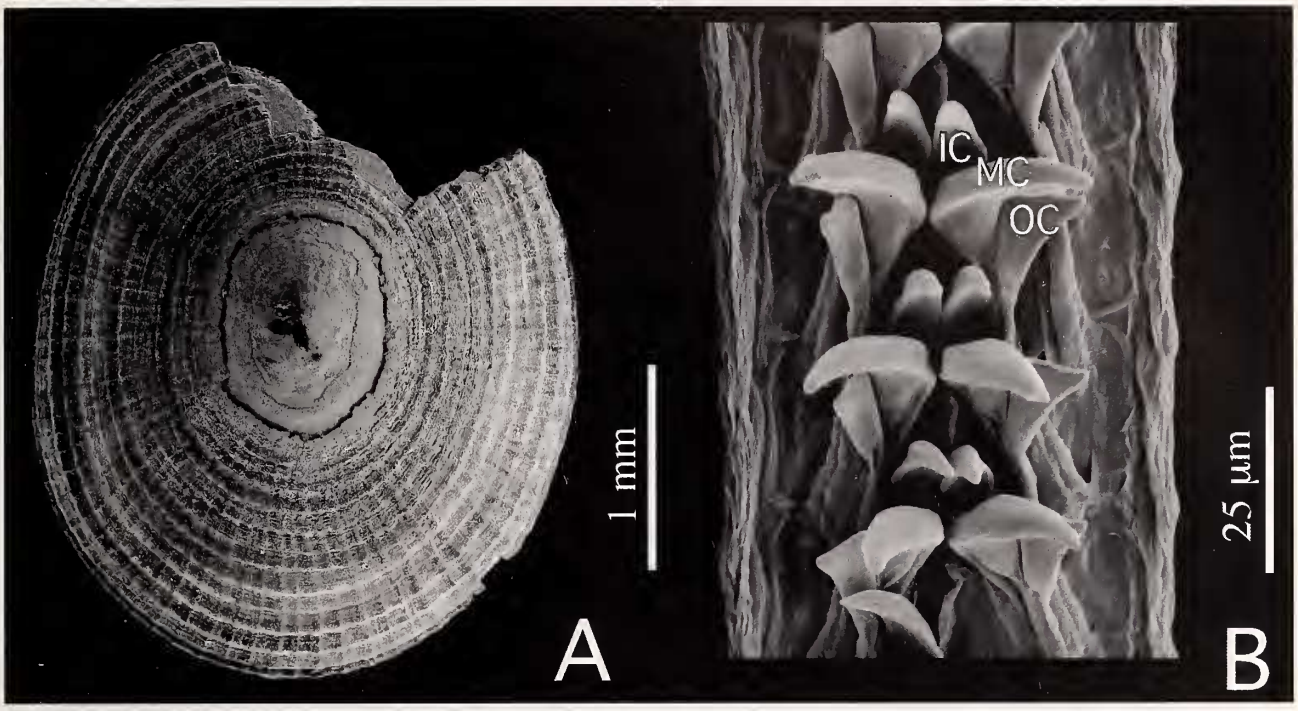



Figure 7. *Bathyacmaea* sp. UMUT RM27960. Sumisu Caldera, 676 m deep, *Shinkai 2000* Dive 1017. **A.** Dorsal view of the shell. **B.** Radula. IC = innermost cusp, MC = middle cusp, OC = outermost cusp.

**New records:** 3 specimens in JAMSTEC (008596 to 008598) from North Knoll of Iheya Ridge, 1049 m deep, *Shinkai 2000* Dive 863; a single specimen in JAMSTEC (0019–88) from Izena Hole, 1430 m deep, *Shinkai 2000* Dive 360.

**Distribution:** Minami Ensei Knoll, Izena Hole, North Knoll of Iheya Ridge, all in Okinawa Trough, 690–1430 m deep.

**Remarks:** This slit limpet is not a common faunal constituent in the vent environment in Okinawa Trough. Since this species was described from Minami Ensei Knoll, 690 m deep, two more specimens have been collected from the North Knoll of Iheya Ridge, 1050 m deep (Okutani & Fujiwara, 2000). The present findings are only additions from the same locality, as well as from the nearby new locality, Izena Hole, in slightly greater depth than the bathymetric range in previous records.

## Family Lepetodrilidae McLean, 1988

## Genus *Lepetodrilus* McLean, 1988

**Diagnosis:** Shell patelliform to broadly coiled; apex situated posteriorly in midline or at slightly posterior right, not in highest position of shell in most speices. Anterior lope long, convex; posterior slope short, concave in lateral view. Protoconch paucispiral, sculptured with fine pits. Periostracum thick, reflected inside at shell margin. Radula rhipidoglossate with formula n-5-1-5-n. Central tooth shortest of all. Five pairs of lateral teeth in inverted V-configuration with third pair at midpoint; first pair particularly prominent. For anatomical characters, see McLean (1988), Fretter (1988) and Sasaki (1998).

### *Lepetodrilus nux* (Okutani, Fujikura & Sasaki, 1993)

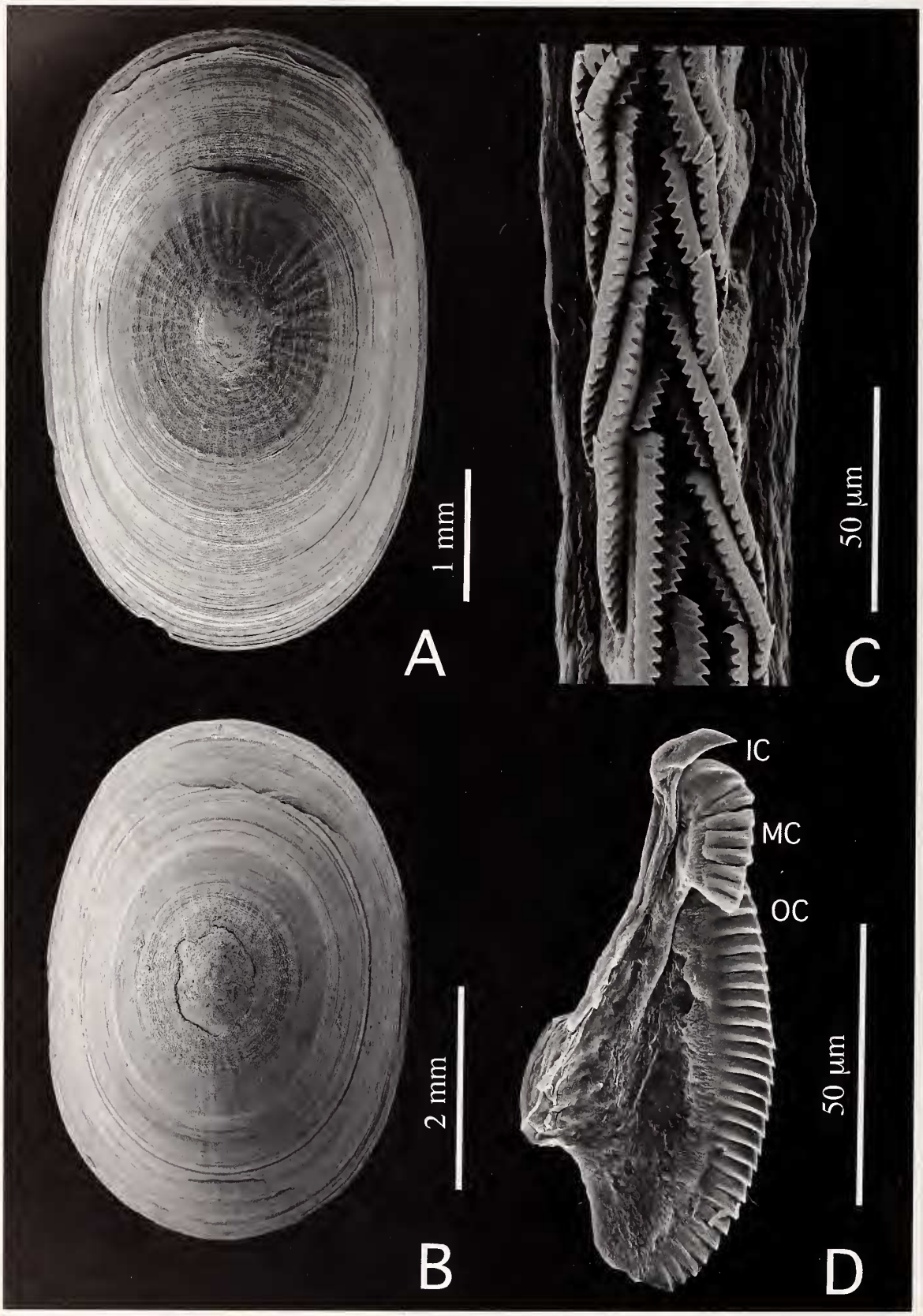
(Figure 11)

*Rhyncopelta? nux* Okutani, Fujikura & Sasaki, 1993: 134, figs. 30–33. *Lepetodrilus nux*: Sasaki, 1998: 94, figs. 62, 63a–e, 64a–d, 65a–h; Sasaki, 2000: 35, pl. 7, fig. 1.

**New records:** 50 specimens in JAMSTEC (006612 to 00661) from North Knoll of Iheya Ridge, 990 m deep, *Shinkai 2000* Dive 978 and over 170 specimens in JAM-

←

Figure 6. *Bathyacmaea* ***subnipponica*** Sasaki, Okutani & Fujikura, sp. nov. UMUT RM27959. Ryuyo Canyon, 1100 m deep, *Shinkai 2000* Dive 898. **A–C.** Shell. **A.** Dorsal view. **B.** Ventral view. **C.** Left lateral view. **D–G.** Radula. **D.** Dorsal view of intact radular teeth. IC = innermost cusp, MC = middle cusp, OC = outermost cusp. **E.** Intact radular teeth slightly inclined forward, showing connection of three cusps. **F.** Long shaft and its attachment on basal plates exposed on the left side. **G.** Basal plates with all radular teeth removed.


A
1 mm
C
50 µm
B
2 mm
IC
MC
OC
D
50 µm

STEC (010754 to 010933) from Iheya Ridge, 1390 m deep, *Shinkai 2000* Dive 672.

**Distribution:** Izena Hole, North Knoll of Iheya Ridge, 990–1390 m deep.

**Remarks:** This species was questionably described as a peltospiroid species, but Sasaki (1998) confirmed that it is a member of *Lepetodrilus* on anatomical grounds. All specimens studied by Sasaki (1998) were of nearly maximum size for this species and they were revealed to be female by reproductive anatomy. So far, no descriptions have been made on the anatomy of male specimens in this species.

Besides many adult specimens, very young specimens with intact protoconch were collected for the first time in the material in this study. The protoconch is well delimited from the teleoconch, 190 μm in maximum length, and covered with sharply demarcated, uniform and shallow pits on its surface (Figure 13D). The early teleoconch whorl is characterized by regularly spaced growth lamellae and obsolete radial threads, both of which are obscured with growth. McLean (1988) described the protoconch of some representatives of the genus *Lepetodrilus* as 120 to 130 μm in maximum length but did not mention the sculpture. The protoconch of *L. atlanticus* illustrated by Warén & Bouchet (2001) has a much coarser pitted sculpture with a diameter 200 μm, and the pits are spirally arranged to some extent.

## Order NERITOPSINA

## Family PHENACOLEPADIDAE Pilsbry, 1895

## Genus *Shinkailepas* Okutani, Saito & Hashimoto, 1989

**Diagnosis:** Shell limpet-shaped; apex located near posterior end or slightly on right side; protoconch multispiral; periostracum very thin. Shell densely penetrated by thin mantle papillae; corresponding minute pores clearly visible on inner surface. Operculum entirely inside of animal, calcified anteriorly, corneous posteriorly; initial part with paucispiral line around nucleus distinguished by subsequent non-spiral incremental lines. Radula rhipidoglossate with formula n-4-1-4-n. Central tooth quadrate with indistinct cusp. First lateral teeth elongate obliquely; second and third teeth smaller; fourth lateral teeth of moderate size and nearly straight longitudinally. Right cephalic lappet of animal transformed into penis with seminal groove in male.

### *Shinkailepas **myojinensis*** Sasaki, Okutani & Fujikura, sp. nov.

(Figures 12, 13)

**Type material:** Holotype (UMUT RM27970), paratype #1 (UMUT RM27971), paratype #2 (UMUT RM27972), paratype #3 (UMUT RM27973), and 24 paratypes in JAMSTEC (017095 to 017118) all from Myojin Knoll, 1288–1340 m deep, *Shinkai 2000* Dive 1112; 21 paratypes in JAMSTEC (016739 to 016760) from the same locality, 1260–1290 m deep, *Shinkai 2000* Dive 1115.

**Diagnosis:** Shell elongated, symmetrical in outline; apertural lateral margins nearly parallel; apex adjacent to posterior end. Surface sculptured by fine granulous radial riblets. Operculum wider than long with anterior left corner strongly projected. Lateral teeth of radula indented with five denticles in the second teeth and with five to six denticles in the fourth teeth.

**Description:** Shell low-capuliform elongate oval, with subparallel-sided margins. Protoconch multispiral, involute, attaining 660 μm in maximum length, smooth externally except for delicate growth lines (Figures 13C, D); initial part of protoconch embedded at apex, visible only in central part. Aperture of juvenile abruptly expanded to become limpet form (Figures 13A, B). Apex of grown teleoconch weakly inclined toward posterior right, situated at margin after metamorphosis but shifted inside with growth, finally situated at about 10% SL ahead. Aperture completely flat and straight in lateral view. Exterior surface ornamented with radial riblets being granulous or even finely spinulous; secondary riblets intercalated between equally spaced primary riblets; all kinds of sculpture disappearing toward shell margin in adult (Figures 12A, B). Surface coated with extremely thin, yellowish periostracum, frequently deposited by black substance in apical to middle portions. Internal surface dull grayish centrally. Apertural margin of interior flattened, somewhat brimlike; its posterior side thickened with shelflike septum reaching 25% of SL. Interior area except margin and septum densely pitted with numerous pores of various size; some of them penetrating whole thickness of shell, opening exteriorly (Figures 12A–C).

Operculum fragile, trapezoidal with anterior side shorter than posterior, calcified ventrally at anterior two-thirds, corneous at posterior one-third. Anterior margin concave, posterior margin convex, lateral margins straight; anterior right corner obtusely protruded. Nucleus situated near left margin. Initial part around nucleus spirally coiling, dis-

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Figure 8. *Serradonta **kanesunosensis*** Sasaki, Okutani & Fujikura, sp. nov. Kanesunose Bank, Nankai Trough, 322 m deep, *Shinkai 2000* Dive 816. **A, B.** Dorsal view of the shell. **A.** Holotype (UMUT RM27961). **B.** Paratype #1 (UMUT RM27962). **C, D.** Radular teeth of holotype (UMUT RM27961). **C.** Dorsal view of the radula. **D.** Inner side view of single right radular tooth. IC = innermost cusp, MC = middle cusp, OC = outermost cusp.

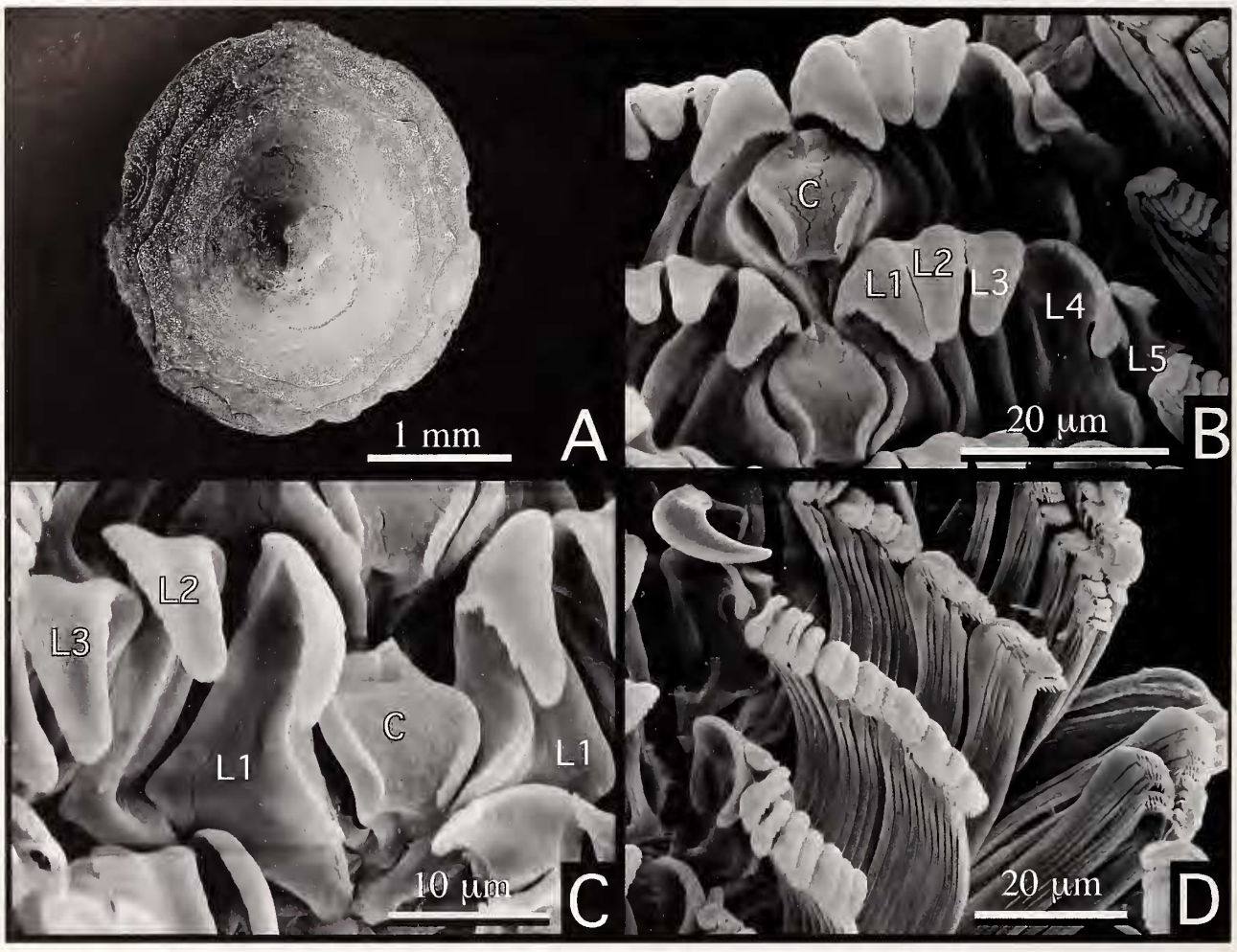


Figure 9. *Pyropelta* ***yamato*** Sasaki, Okutani & Fujikura, sp. nov. Sumisu Caldera, 676 m deep, *Shinaki 2000* Dive 1017. UMUT RM27964. **A.** Dorsal view of the shell. **B, C.** Central (C) to fifth lateral (L1–L5) teeth. **D.** Right marginal teeth.

tinctly demarcated off from remaining part lacking spiral growth lines.

Radula rhipidoglossate with formula of n-4-1-4-n. Central tooth (C in Figure 12E) quadrate, longer than wide, with no distinct cusp on top, but with weakly concave rim and steplike rectangular depression in middle. First lateral teeth (1L) elongate parallelogrammatic; anterior margin inrolled, toothless; lateral margin adjoining second teeth, reinforced by reflected oblique keel; anterior outer corner extended as smooth small plate. Second lateral teeth (L2) with small cutting edge, armored with five low cusps. Third lateral teeth (L3) with no cusps on anterior top, but winglike projections behind top interlocked with serrated teeth. Fourth lateral teeth (L4) with five to six cusps among which innermost one is the largest; shaft weakly curved, carrying undulating axial flexures. Marginal teeth numerous in number, probably more than 60 in single row; cutting edge small, serrated with four to eight sharp denticles; deep embayment present below inflected cusp; shaft slender, gently curved.

**Measurements (SL × SW × SH in mm):** Holotype: 6.8 × 5.2 × 2.5, paratype #1 6.2 × 5.2 × 2.3, paratype #2 8.0 × 6.9 × 3.1, paratype #3 6.3 × 4.7 × 2.7.

**Distribution:** Myojin Knoll, Ogasawara Ridge, 1260–1340 m deep.

**Etymology:** The specific name is given after the name of type locality.

**Remarks:** Three species have been described in the genus *Shinkailepas,* namely, *S. kaikatensis* Okutani, Saito & Hashimoto, 1989, from Kaikata Seamount, off Ogasawara Islands, *S. tufari* Beck, 1992 from Manus Basin, southeastern Pacific, and *S. briandi* Warén and Bouchet, 2001 from Mid-Atlantric Ridge. *S.* ***myoiueusis*** is markedly differentiated from *S. kaikatensis* in opercular char-

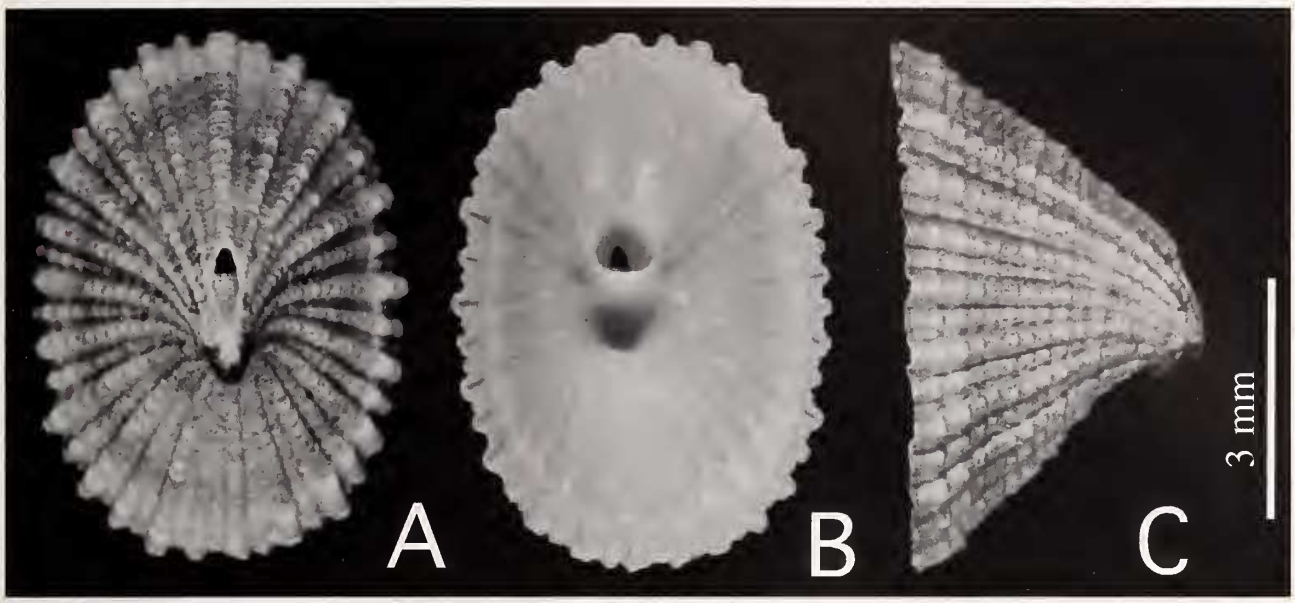


Figure 10. *Puncturella parvinobilis* Okutani, Fujikura & Sasaki, 1993. UMUT RM27965. North Knoll of Iheya Ridge, 1049 m deep, *Shinkai 2000* Dive 863. **A.** Dorsal view. **B.** Ventral view. **C.** Left lateral view.

acters: The operculum is longitudinally longer than wide with rounded corners in *S. kaikatensis,* but in contrast, it is wider than long with the anterior left corner more prominently protruding in *S.* ***myojinensis.*** In shell characters, *S.* ***myojinensis*** has a more elongate apertural outline and finer exterior sculpture than *S. kaikatensis.* In radular characters, *S. kaikatensis* has a more flared shaft in the first lateral teeth and possesses a smaller number and stronger cusps on the fourth lateral teeth.

*Shinkailepas tufari* is also distinct from *S.* ***myojinensis*** in having a more posteriorly positioned apex at similar shell length, more roughened radial ribs, smaller extension of inner septum, and more rounded form of operculum (Beck, 1992a: figs. 1, 2, 4). In radular characters, the reflection of anterior margin in the first lateral teeth is more pronounced in *S. tufari* (Beck, 1992a: fig. 3).

*Shinkailepas briandi* is clearly distinguished from *S.* ***myojinensis*** in retaining a degree of coiling, granular riblets of nearly constant thickness, and transversely trapezoid operculum (Warén & Bouchet, 2001: figs. 16a, b, 32). In radular characters, cutting edges of second and fourth lateral teeth are less denticulated, and the shaft of the third lateral tooth is attenuated in *S. briandi* (Warén & Bouchet, 2001: fig. 31d).

*Shinkailepas* sp.

(Figure 14)

**Material examined:** Single specimen (UMUT RM 27976) from North Knoll of Iheya Ridge, 976 m deep, *Shinkai 2000* Dive 975.

**Measurement (SL × SW × SH in mm):** 9.2 × 7.1 × 2.9.

**Remarks:** This species is slightly different from the above species in exhibiting more prominent exterior ribs which are not very granulous. However, we cannot make taxonomic judgment with confidence because sufficient specimens of equivalent size are not available for comparison between these two species. Legitimate identification therefore must await collection of new material.

## DISCUSSION

The dominance of patelliform gastropods with docoglossate or rhipidoglossate radula is one of the prominent characteristics of vent/seep molluscan faunas (Warén & Bouchet, 2001; Lindberg & Ponder, 2001). These limpets belong to various higher taxa and obviously do not constitute a monophyletic group. The possession of limpet form is the most conspicuous case of multiple convergence in gastropod shell morphology. Among various gastropod limpets, all patellogastropods (Eogastropoda) secrete a symmetrically tubular protoconch (primary limpets), while limpets of the remaining higher taxa (Orthogastropoda) originate from a spirally coiled form in ontogeny and probably also in phylogeny (secondary limpets) (Haszprunar, 1988; Ponder & Lindberg, 1997; Sasaki, 1998). It also should be noted that no caenogastropods or heterobranchs have achieved a limpet form in chemosynthetic communities.

The limpets from vent/seep sites are currently classified into nine families as mentioned below. Among them, six families, Neoleptopsidae, Acmaeidae, Pyropeltidae, Fissurellidae, Lepetodrilidae, and Shinkailepadidae are known from Japanese vent/seep sites (Table 2).

(1) Neolepetopsidae (Patellogastropoda): Three genera

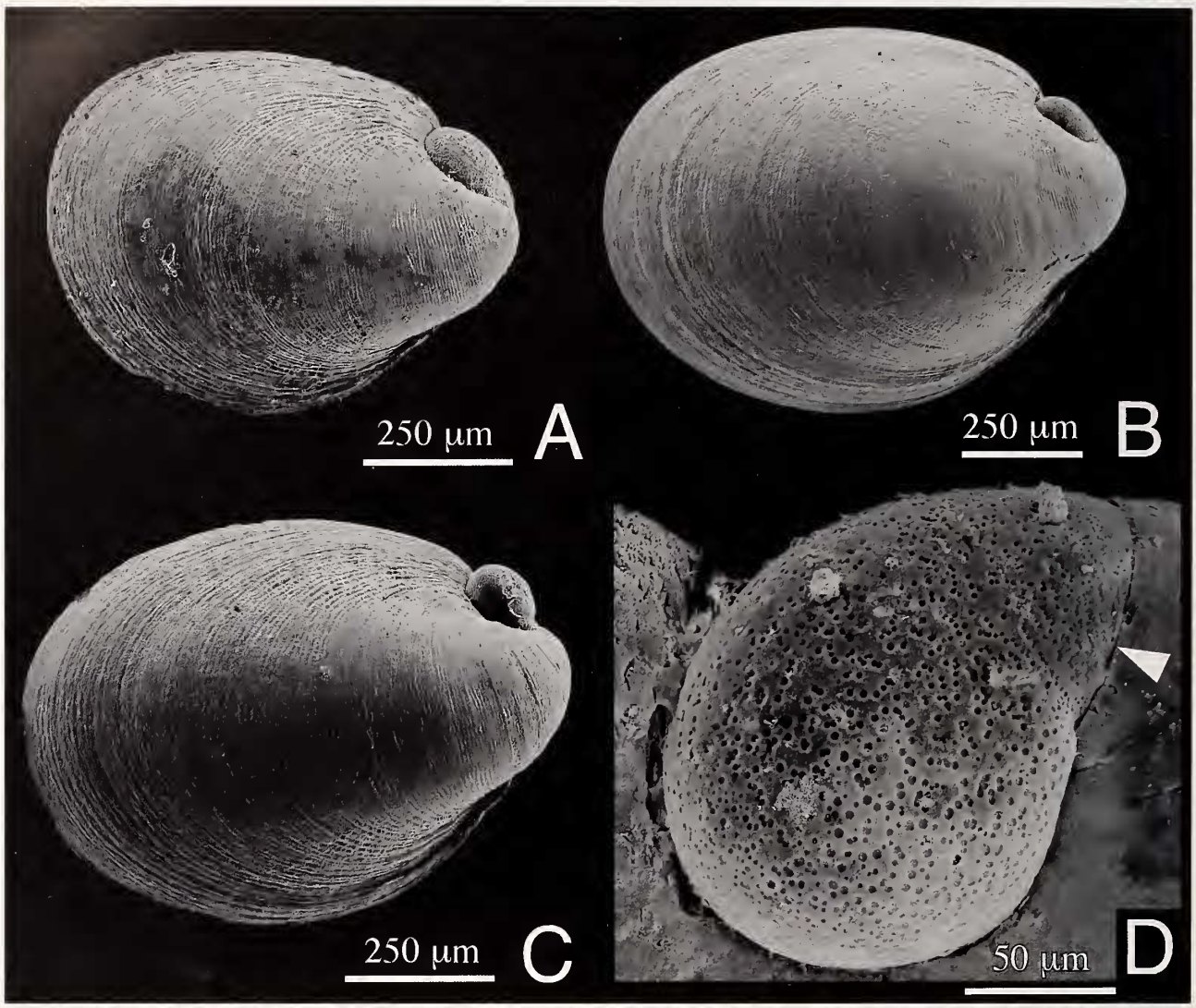


Figure 11. *Lepetodrilus nux* (Okutani, Fujikura & Sasaki, 1993). North Knoll of Iheya Ridge 1390 m deep, *Shinaki 2000* Dive 672. **A–C.** Dorsal view of juvenile shells. **D.** Enlarged view of the protoconch. Arrowhead indicates the proto- and teleoconch boundary. A. UMUT RM27966. B, D. UMUT RM27967. C. UMUT RM27968.

have been described so far in this family. *Neolepetopsis* McLean, 1990, and *Eulepetopsis* McLean, 1990, are known from the Eastern Pacific (McLean, 1990a), and *Paralepetopsis* McLean, 1990, from off Florida (McLean, 1990a), the Mid-Atlantic Ridge, and off Japan (Warén & Bouchet, 2001) and the Southwest Pacific (Beck, 1996). The description of a single specimen of *Paralepetopsis lepichoni* Warén & Bouchet, 2001, from Nankai Trough off central Japan is the only record of the family from the Northwest Pacific.

(2) Acmaeidae (Patellogastropoda): It has been shown that vent/seep-associated acmaeid limpets are most diversified around Japan. In the genus *Bathyacmaea* at least five species have been collected around Japan, and one more species is known from the Southwest Pacific (Beck,

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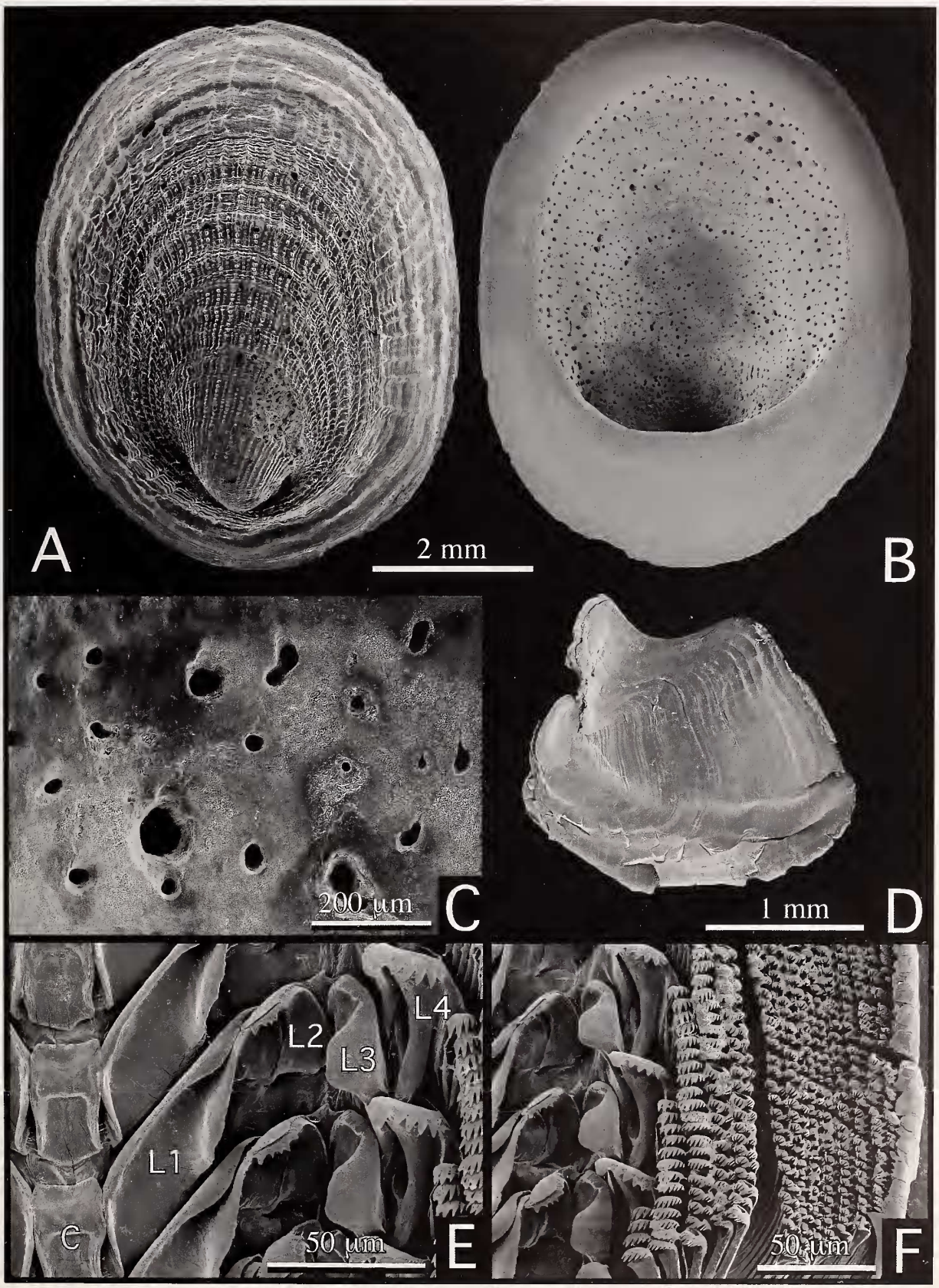
Figure 12. *Shinkailepas* ***myojinensis*** Sasaki, Okutani & Fujikura, sp. nov. Myojin Knoll, 1260–1290 m deep, *Shinkai 2000* Dive 1115. **A–C.** Shell of holotype (UMUT RM27969). **A.** Dorsal view. **B.** Ventral view. **C.** Enlarged view of shell pores opening on interior surface. **D.** Dorsal view of the operculum (UMUT RM 27973). **E, F.** Radula of holotype (UMUT RM27969). **E.** Right rows of central (C) to lateral (L1–L4) teeth. **F.** Lateral to marginal teeth.


A
2 mm
B
200 µm
C
1 mm
D
L4
L2
L3
L1
e
50 µm
E
50 µm
F

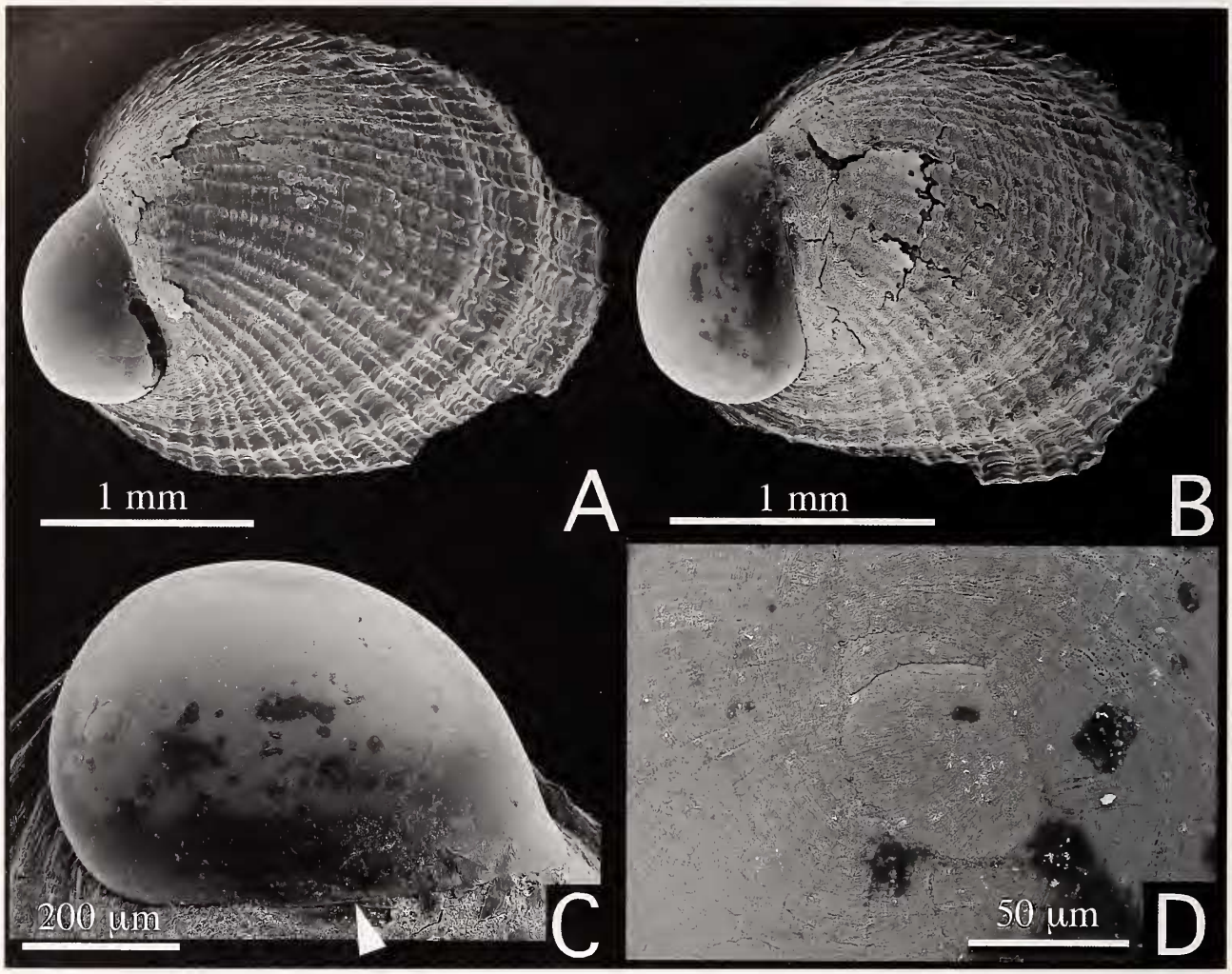



Figure 13. *Shinkailepas* ***myojineusis*** Sasaki, Okutani & Fujikura, sp. nov. Myojin Knoll, 1260–1290 m deep, *Shinkai 2000* Dive 1115. **A, B.** Dorsal view of juvenile shells. **C.** Protoconch. **D.** Magnified view of initial part of protoconch whorls. A. UMUT RM27974. B–D. UMUT RM27975.

1996). The genus *Serradonta,* including two species, is endemic to off the central part of the Japanese mainland (Nankai and Sagami Troughs).

(3) Pyropeltidae (Cocculiniformia): Four species of *Pyropelta* McLean & Haszprunar, 1987, have been reported from the Northeast Pacific (McLean & Haszprunar, 1987; McLean, 1992a) and from the Southwest Pacific (Beck, 1996). The occurrence of *P.* ***yamato*** in Sumisu Caldera is the first record of the family from the Northwest Pacific.

(4) Fissurellidae (Vetigastropoda): Although the majority of its members inhabit non-chemosynthetic environments, the genus *Puncturella* Lowe, 1827, includes two species from Okinawa Trough (Okutani et al., 1993) and one species from Edison Seamount, Southwest Pacific (Beck, 1996). Other vent-associated fissurellids, *Clathrosepta* McLean & Geiger, 1998, and *Cornisepta* McLean & Geiger, 1998, have not yet been found in the Northwest Pacific (McLean & Geiger, 1998).

(5) Sutilizonidae (Vetigastropoda): This group was originally described as a subfamily of the Scissurellidae by McLean (1989a) and later treated as a separate family by Warén & Bouchet (2001). Among three included genera, *Temnociuclis* McLean, 1989, and *Temnozaga* McLean, 1989, have been recorded only from the Eastern Pacific, while *Sutilizona* McLean, 1989, has been described from the Eastern Pacific and Mid-Atlantic Ridge (McLean, 1989a; Warén & Bouchet, 2001).

(6) Lepetodrilidae (Vetigastropoda): The genus *Lepetodrilus* is very widely distributed in the Western Pacific (Okinawa Trough and Manus Basin), Eastern Pacific, and Mid-Atlantic Ridge (McLean, 1988, 1993; Beck, 1993; Okutani et al., 1993; Warén & Bouchet, 2001). In Japan,

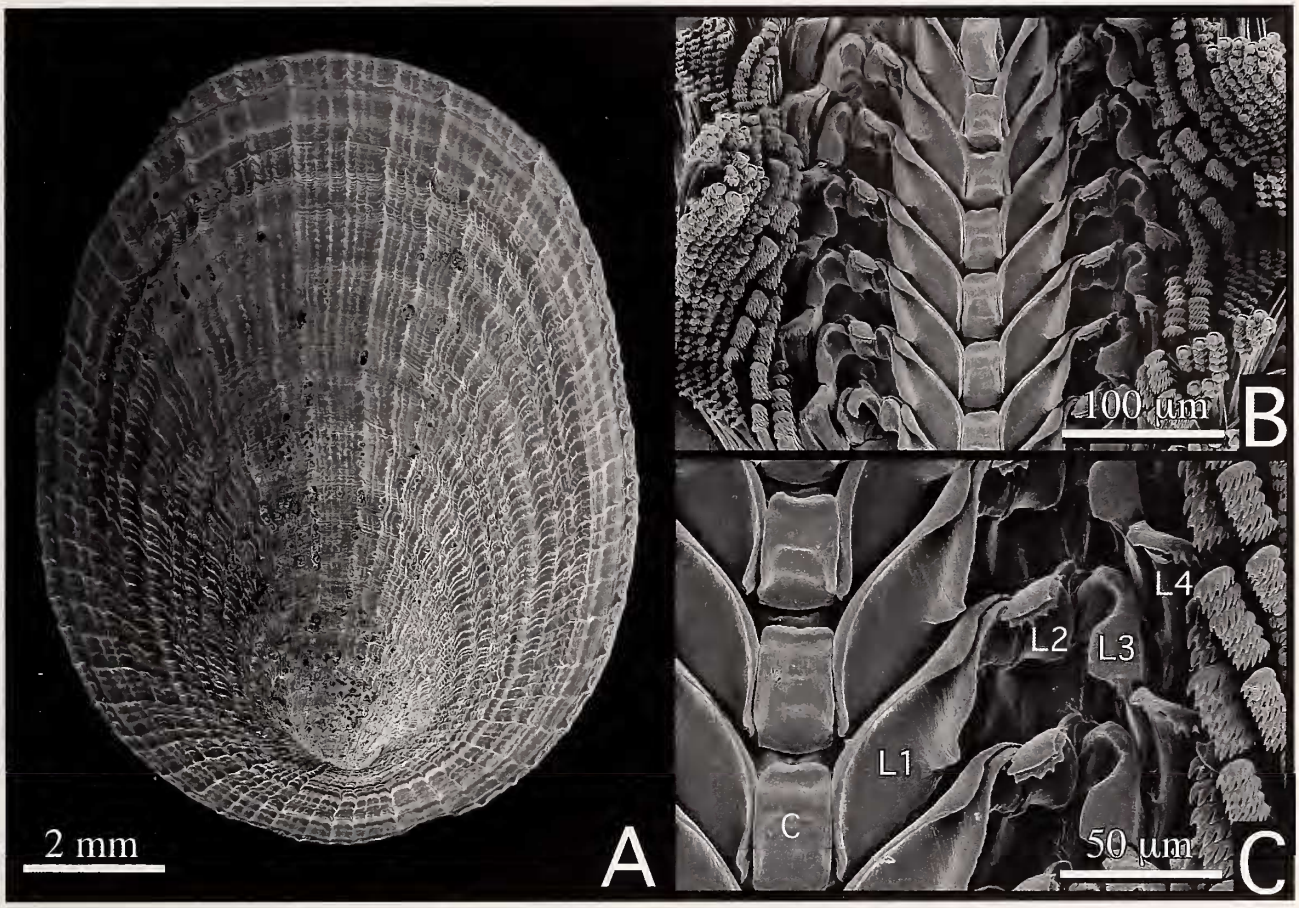



Figure 14. *Shinkailepas* sp. North Knoll of Iheya Ridge, 976 m deep, *Shinkai 2000* Dive 975. UMUT RM27976. **A.** Dorsal view of shell. **B, C.** Radula.

Table 2

Geographic distribution of limpets from vent/seep sites in western Pacific at generic level. ES = Edison Seamount, F = Fiji, KS = Kaikata Seamount, M = Manus, MK = Myojin Knoll, MT = Mariana Trench, NT = Nankai Trough, OT = Okinawa Trough, SB = Sagami Bay, SC = Sumisu Caldera.

| Family | Genus | OT | NT | SB | MK | SC | KS | MT | M | ES | F |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Neolepetopsidae | *Paralepetopsis* | | + | | | | | | | + | |
| Acmaeidae | *Bathyacmaea* | + | + | + | | + | | | + | + | |
| Acmaeidae | *Serradonta* | | + | + | | | | | | | |
| Pyropeltidae | *Pyropelta* | | | | | + | | | | + | |
| Fisurellidae | *Puncturella* | + | | | | | | | | + | |
| Fissurellidae | *Clathrosepta* | | | | | | | | + | | |
| Clypeosecticae | *Pseudorimula* | | | | | | | + | | | + |
| Lepetodrilidae | *Lepetodrilus* | + | | | | | | | + | | |
| Neomphalidae | *Symmetromphalus* | | | | | | | + | + | | + |
| Phenacolepadidae | *Shinkailepas* | + | | | + | | + | + | + | | + |
| Phenacolepadidae | *Olgasolaris* | | | | | | | | | + | + |

Table 3

Geographic distribution of limpets from vent/seep sites in Japan at species level. IH = Izena Hhole, IR = Ihera Ridge, KS = Kaikata Seamount, MEK = Minamiensei Knoll, MK = Myojin Knoll, NIR = North Knoll of Iheya Ridge, NT = Nankai Trough, OT = Okinawa Trough, SB = Sagami Bay, SC = Sumisu Caldear.

| Species | OT | | | | NT | SB | MK | SC | KS |
|---|---|---|---|---|---|---|---|---|---|
| | NIR | IR | IH | MEK | | | | | |
| *Paralepetopsis lepichoni* | | | | | + | | | | |
| *Bathyacmaea nipponica* | | | | | | + | | | |
| *Bathyacmaea secunda* | + | + | | + | | | | | |
| *Bathyacmaea tertia* | + | | | | | | | | |
| *Bathyacmaea subnipponica* | | | | | + | | | | |
| *Bathyacmaea* sp. | | | | | | | | + | |
| *Serradonta vestimentifericola* | | | | | | + | | | |
| *Serradonta kanesunosensis* | | | | | + | | | | |
| *Pyropelta yamato* | | | | | | | | + | |
| *Puncturella parvinobilis* | + | | + | + | | | | | |
| *Puncturella rimaizenaensis* | | | + | | | | | | |
| *Lepetodrilus nux* | + | + | + | | | | | | |
| *Lepetodrilus japonicus* | | | | + | | | | | |
| *Shinkailepas kaikatensis* | | | | | | | | | + |
| *Shinkailepas myojinensis* | | | | | | | + | | |
| *Shinkailepas* sp. | + | | | | | | | | |

*Lepetodrilus nux* is the most abundant species of gastropod throughout vent sites of the Okinawa Trough, while *L. japonicus* is endemic to a single locality (Okutani et al., 1993). Another genus, *Gorgoleptis* McLean, 1988, is restricted to the East Pacific Rise and Galapagos Rift (McLean, 1988). Two genera, *Clypeosectus* McLean, 1989, and *Pseudorimula* McLean, 1989, were originally described as Clypeosectidae (McLean, 1989a) but were recently included in the Lepetodrilidae by Warén & Bouchet (2001). They are distributed on the East Pacific Rise (*Clypeosectus*) and in the Mariana Trough and on the Mid-Atlantic Ridge (*Pseudorimula*) (McLean, 1989a, 1992b; Warén & Bouchet, 2001).

(7) Neomphalidae (Neomphaloidea): The type genus of the family, *Neomphalus* McLean, 1981, was described from the Galapagos Rift and East Pacific Rise (McLean, 1981). Another limpet-shaped member, *Symmetromphalus* McLean, 1990, is known from the Mariana and Manus Back-Arc Basins (McLean, 1990b; Beck, 1992b). One of the coiled forms of this family, *Retiskenea diploura* Warén and Bouchet, 2001, was reported from the Japan Trench for the first time by Okutani & Fujikuka (2002).

(8) Peltospiridae (Neomphaloidea): Species assigned to this family have been described from the East Pacific Rise, Mid-Atlantic Ridge, and Southwest Pacific (McLean, 1989b; Warén & Bouchet, 1989, 1993). No species in this family is included in the fauna of the Northwest Pacific.

(9) Phenacolepadidae (Ncritopsina): This family (see above for diagnosis) contains two genera, *Shinkailepas* from the Western Pacific and Mid-Atlantic Ridge (Okutani et al., 1989; Hasegawa et al., 1997; Beck, 1992a; Warén & Bouchet, 2001) and *Olgasolaris* Beck, 1992, from the Southwest Pacific (Beck, 1992a). At least two species are distributed at distantly isolated sites along the Izu-Ogasawara Trench in Japan. The occurrence of an unidentified specimen from the Okinawa Trough (herein) suggests possible addition of further new species in the future.

It is apparent that the molluscan fauna of chemosynthetic communities in Japan consists of species endemic to vent/seep sites and totally differs from that of the normal (non-chemosynthesis-based) bathyal to abyssal zone around the Japanese mainland (e.g., Okutani, 1964, 1966, 1968a, b; Okutani & Iwahori, 1992). A summary of present and previous records (Table 3 and Appendix) also indicates that all limpet species were collected only from a single locality or a few localities within a relatively narrow area in the same group of ridges or knolls along in the same trough or trench. This high rate of endemism is prevalent not only in limpets of the northwest Pacific but also in gastropods of the world chemosythetic-based fauna as was already pointed out by Warén & Bouchet (2001).

Tables 2 and 3 suggest that the similarities in faunal composition well reflect geographic closeness among localities. The distribution pattern of limpets indicates possible division of Japanese vent/seep fauna into four geographic groups. (1) Okinawa Trough: This region is characterized by the presence of *Lepetodrilus, Puncturella,* and *Bathyacmaea secunda. L. nux* and *B. secunda* are particularly abundant in several localities. (2) Nankai and Sagami Troughs: The distinctness of this region is shown by the occurrence of the two species of an endemic genus, *Serradonta* (*S. vestimentifericola* and *S.* ***kanesunosensis***), and a similar species pair of *Bathyacmea* (*B. nipponica* and *B.* ***subnipponica***). (3) Izu-Ogasawara Trench:

The limpet fauna of this region contains no species common to other regions. The presence of a distributional barrier between the Izu-Ogasawara and Mariana Trenches is suggested by the absence of *Symmetromphalus* and *Pseudorimula* which are distributed from the Southwest Pacific to the Mariana Trench. (4): Japan Trench: This region is clearly different in that no limpet taxa have hitherto been recorded (Okutani & Fujikura, 2002). Since limpets constitute the majority of Japanese vent/seep-related gastropods, above biogeographic distinction seems to represent a general trend for entire gastropods from such environments. A more comprehensive distributional pattern will be elucidated by our ongoing systematic revision on whole molluscan species from the Okinawa Trough and other Japanese chemosynthetic sites.

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## APPENDIX

## Previous Records of Limpets from Japanese Vent/Seep Sites

### Neolepetopsidae

*Paralepetopsis lepichoni* Warén & Bouchet, 2001: Nankai Trough, 2140 m (Warén & Bouchet, 2001).

### Acmaeidae

*Bathyacmaea nipponica* Okutani, Tsuchida & Fujikura, 1992: Off Hatsushima, Sagami Bay, 1110–1200 m, on shells of *Calyptogena* (Okutani et al. 1992).

*Bathyacmaea secunda* Okutani, Fujikura & Sasaki, 1993: Minami Ensei Knoll, Okinawa Trough (type locality), 700 m (Okutani et al., 1993); Iheya Ridge, Okinawa Trough, 1380 m (Okutani et al., 1993); North Knoll of Iheya Ridge, Okinawa Trough, 1050 m (Okutani & Fujiwara, 2000).

*Serradonta vestimentifericola* Okutani, Tsuchida & Fujikura, 1992: Off Hatsushima, Sagami Bay, 1110–1200 m, on vestimentiferan tubes (Okutani et al., 1992).

### Fissurellidae

*Punturella rimaizenaensis* Okutani, Fujikura & Sasaki, 1993: Izena Hole, Okinawa Trough, 1340 m (Okutani et al., 1993).

*Puncturella parvinobilis* Okutani, Fujikura & Sasaki, 1993: Minami Ensei Knoll, Okinawa Trough, 690 m (Okutani et al., 1993); North Knoll of Iheya Ridge, Okinawa Trough, 1049 m (Okutani & Fujiwara, 2000).

### Lepetodrilidae

*Lepetodrilus nux* (Okutani, Fujikura & Sasaki, 1993): Izena Hole, Okinawa Trough, 1340 m; Iheya Ridge, Okinawa Trough, 1350 m (Okutani et al., 1993).

*Lepetodrilus japonicus* Okutani, Fujikura & Sasaki, 1993: Minami Ensei Knoll, Okinawa Trough, 710 m, 700 m (Okutani et al., 1993).

### Shinkailepadidae

*Shinkailepas kaikatensis* Okutani, Saito, & Hashimoto, 1989: Kaikata Seamount, 470 m (Okutani et al., 1989).